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Species composition, abundance and seasonal occurrence of the sap beetles (Coleoptera: Nitidulidae) in a peri-urban area of Kolkata, India

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Abstract: 【Aim】A large majority of the sap beetle fauna of India thrives on rotten fruits and vegetables and their populations show considerable seasonal fluctuations over the year. It has been hypothesized that the population of sap beetles are largely dependent on environmental variables like temperature, humidity and rainfall. 【Methods】 The species composition, seasonal incidence and population structure of sap beetles (Coleoptera: Nitidulidae) were investigated in Garia, a peri-urban area of Kolkata, India from 2013 to 2015. Period of their activity, seasonal abundance and factors influencing their occurrence were recorded. 【Results】 Altogether six species were encountered in varying numbers in the peri-urban area of Kolkata, India during the study period. The most commonly collected sap beetle was *Urophorus humeralis*. This species was encountered for the largest number and during almost all months of the year. Other common species were *Epuraea ocularis* and *E. luteola*. Different species entered into the trap in successive stages of the fermenting food. *Epuraea* spp. were intercepted in the first 12 h while *U. humeralis* was mostly found in later successive stage when the food in the bait trap was severely rotten. The species richness was the highest in an optimum range of atmospheric temperature (22℃ to 29℃) and relative humidity (82.5% to 86%), demonstrating that these environmental variables have considerable influence over sap beetle population. 【Conclusion】Major fruits and vegetables grow during the post-monsoon season in Kolkata. Sap beetles which feed on these crops show the highest incidence both in terms of species richness and abundance during the post-monsoon season. The study result may help in designing effective field management strategy for these beetles.

Key words: Nitidulidae; sap beetles; species diversity; seasonal variation; environmental factors; Kolkata; India

1 INTRODUCTION

Since the sap beetles are minor pests to fruits and vegetables, it was necessary to study their seasonal incidence and community compositions in order to design effective pest control strategy. An important aspect of studying community structure of the beetles is the distribution of the beetles in natural habitats (spatial distribution) and fluctuation of population abundances of beetles over time (temporal distribution) and it is essential to understand the fundamental ecology of beetles especially species composition, abundance, and role of environmental factors on seasonal fluctuations. The population dynamics of beetles depends on several environmental factors like temperature, rainfall, humidity, *etc.* as well as some physical factors like soil properties, vegetative structure, pollution, *etc.* and biological factors like other associated animals, *etc.* Beetles often develop strategies to maximize fitness and minimize metabolic costs of survival in a difficult environment either by increasing fecundity or decreasing metabolic rate (Kistler, 1982). According to Dahlhoff *et al.* (2008), montane leaf beetles experience elevated temperature during summertime oviposition and larval development which causes physiological stress and reduces fecundity. Eggs of vedalia beetle maintained at 34℃ showed reduced hatching and survival of larvae whereas eggs maintained at 37℃ failed to hatch. The developmental time from egg to imago decreased considerably with increase in temperature up to 25℃ (Grafton-Cardwell *et al.*, 2005). Al-Digail *et al.* (2012) observed that environmental temperature and relative humidity affect the biological activities of a coccinellid beetle species through their effect on reproduction and development. It was observed that maximum abundance of these beetles was witnessed in March due to favorable conditions of temperature and

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humidity for reproduction. Small size and high surface to volume ratio in insects make it essential to prevent lethal dessication in dry climatic condition with warm temperature and low humidity (Aubin, 2017).

The present study of sap beetle interception in a food bait trap in a small garden area provided the seasonal variation of their population and the role of environmental factors that influence it. Seasonal occurrence of these sap beetles in nature was not studied earlier in India. The trapping method was devised considering the feeding habit of the sap beetles, which feed primarily on rotten fruits and vegetables. Hence, food bait trap containing banana skin and beer was used. It served as an effective mode for sap beetle interception as the banana skin served as a place of refuge for the tiny beetles and they often hide in the cracks and crevices of the skin while the scent of beer mimics the scent of fermenting fruit which attracts the sap beetles all the more towards the trap. Previously, baited cans (Luckmann, 1963; Foott and Hybsky, 1976), Japanese beetle-type vane traps (Alm *et al*., 1985) and glass jar-based funnel traps (Smilanick *et al*., 1978) were used to collect beetles. These traps had limited efficacy. Dowd *et al*. (1992) had devised an insect trap to capture sap beetles and other flying insects with the use of polyvinyl chloride (PVC) and screen wire which captured more beetles. Although the trap was durable and made from readily available materials, it was quite expensive. Bakke (1999) used Malaise trap, window and emergence trap for sampling of saproxylic beetles in Southern Norway. All these traps did not give any information about the feeding habit of the beetles. Hence, considering varying effectiveness of the above traps, and also to reduce the cost of trapping methods, food bait trap was used in our study.

We studied the biology of a sap beetle species in simulated natural condition in laboratory where we found considerable mortality of the species in immature stage. However, the life table for natural population dynamics has not been studied. These aspects can be studied and explored in future to ascertain the population dynamics of these beetles in nature.

Sap beetle belongs to family Nitidulidae of the superfamily Cucujoidea in the suborder Polyphaga of the order Coleoptera (beetles). Nitidulidae (sap beetles) is a large family and near about 4 500 species are described worldwide although many more remain undescribed (Zhang, 2011). The body length of Nitidulidae adults range from about 1 to 12 mm. Bodies are often depressed, usually oval shaped, but some elongated. The adults often bear red or yellow spots. The head is prognathous. The antennae are 11-segmented, with the apical three segments forming a club. The antenna is often received in a groove on the underside of the head. The tarsal formula is 5-5-5 (Habeck, 2002; Dasgupta, 2017).

Sap beetles display a wide range of feeding habits, though they are generally considered to be saprophagous and mycetophagous (Habeck, 2005). They are found on a broad range of substrates including sap, flowers, fruits, macrofungi, carrion, animal carcasses, human cadavers and decaying plant matter (Habeck, 2002, 2005). Beetles of the genus *Nitidula* are forensically important (Tüzün *et al*., 2010; Ortloff *et al*., 2014). Many species are dependent on forest habitats during at least some parts of their life cycle (Zeran *et al*., 2006). The members of this family are considered minor agricultural pests, including *Carpophilus lugubris* Murray, 1864 and *Glischrochilus quadrisignatus* (Say, 1835) on corn and *Stelidota geminata* (Say, 1825) on strawberries and raspberries (Dowd and Nelsen, 1994; Blackmer and Phelan, 1995). *Glischrochilus quadrisignatus* is also a primary vector of the oak wilt pathogen, *Ceratocystis fagacearum* (Bretz) Hunt (Ceratocystidaceae) (Cease and Juzwik, 2001).

Although small sized, nitidulid beetles make up an interesting component of the forest arthropod community, but there have been few studies of their ecology outside of agricultural landscapes (Zeran *et al*., 2006). Nitidulid beetles were studied in relation to seasonal abundance using different modes of sampling. Kehat *et al*. (1983) studied the seasonal abundance of sap beetles in date plantations in Israel. Gough and Hamacek (1989) studied the seasonal incidence of *Macroura concolor* (Macleay) and their relationship with bud falling in *Hibiscus rosasinensis* in Southern Queensland, Australia. James *et al*. (1995) studied the nitidulid fauna and their seasonal abundance in four stone fruit orchards in Australia using fermenting bread and aggregation pheromone as trap. Bakke (1999) studied the diversity of saproxylic beetles in a forest in Norway and compared the efficacy of different trapping methods in sampling adult population of the sap beetles. Juzwik *et al*. (2004) studied the seasonal abundance of sap beetle species visiting fresh wounds on healthy oaks in Minnesota. Zeran *et al*. (2006) studied diversity of sap beetles in managed and old-growth forests in southeastern Ontario, Canada.

Alinvi *et al*. (2007) studied the species assemblage and diversity of saproxylic sap beetles using various sieving techniques and traps. In Indian context, taxonomy of nitidulid beetle is being studied in recent time (Dasgupta *et al*., 2013, 2015, 2016a, 2016b; Pal and Dasgupta, 2014, 2017; Dasgupta and Pal, 2016, 2019), however, study on occurrence and population structures of the sap beetles is very scanty.

The present study dealt with the species composition, seasonal incidence and population structure of sap beetles from a peri-urban area of India for the period of two years. The aim of the study was to ascertain that environmental variables have considerable influence over the population of sap beetles. Since these beetles feed on crops and some are also associated with flowers, this study might be useful in designing effective field management strategy for pest control and sustainable use of these beetles in agriculture.

2 MATERIALS AND METHODS

2.1 Study site

The study was conducted in a cultivated plot containing different vegetable and flowering plants in a peri-urban area named Garia (22.466531°N, 88.383014°E), situated in the southern part of Kolkata metropolitan city in West Bengal state. In the last five years, developmental activities got momentum in this area. The area is represented with large evergreen and deciduous trees, and there are also fruit orchards, plant nurseries and gardens in some parts. Due to greenery, this region is an abode of varieties of insects and birds. The area was chosen for feasibility of conducting regular study close to farmland areas at the outskirt of the city of Kolkata. It was a fenced garden area of 25 m × 30 m containing seasonal flowers, fruit trees like banana, mango, guava, coconut trees and seasonal crops. The study was conducted in three different seasons, *viz*., pre-monsoon (middle of March to middle of June), monsoon (middle of June to middle of October) and post-monsoon (mid-November to February) period over the two successive years, 2013 –2015.

2.2 Specimen collection and identification

Locally abundant trees, mostly perennial and easy to recognize in the field (*e. g*., eggplant, banana plants, coconut trees, mango and guava trees), were selected for the study. The sampling was made by using food bait trap method as described by Dasgupta *et al*. (2013). A two litre volume of plastic bottle (34 cm in length and 9 cm in diameter) was taken and a horizontal incision was made on the bottle by a sharp blade at about two inches below the bottle neck. The entire neck area was chopped off from the bottle and kept aside. The chopped off portion of the bottle was then inverted and re-inserted into the bottle thereby forming a short funnel. Food in the form of banana skin (three in number) and 40 mL of beer was kept in that container. The junction of the funnel and the bottle was sealed with tape and two holes were made onto the sides of the plastic bottle to tie a string on either side so that the device could be hanged. The traps were fastened to tree trunks with nylon cord at about 2 m above ground. Five of these traps were placed in a garden square plot of 15 m × 15 m with four traps placed at the four corners of the square area and one at the centre of the square plot. The scent of beer mimics the scent of fermenting sap, which attracts sap beetles along with other insects. The nitidulid beetles along with other insects entered the trap from the bottle mouth of the funnel and fed on the food. The traps were kept in the garden for 48 h before being taken to laboratory. Retrieved materials from all the five traps were combined and sorted out and results of the sampling were noted. The process was repeated every fortnight throughout the entire study period.

The larvae and adults of sap beetles and other fauna were taken out from the traps alive by soft hair brush and preserved in 70% ethanol in a glass tube. Sap beetles were identified to generic and species level following standard taxonomic procedures (Dasgupta, 2017).

2.3 Data analyses

The meteorological data such as temperature (℃), relative humidity (%) and rainfall (mm) of the study area for the period April 2013 to March 2015 were collected on monthly basis from Meteorological Department, Ministry of Earth Sciences, Government of India. Species composition (%), temperature (℃), relative humidity (%) and rainfall (mm) data of all months of two consecutive years were analyzed using one-way analysis of variance (ANOVA) to confirm the significance among the mean values (Zar, 1999). Tukey (HSD) test was carried out to evaluate pair-wise multiple comparisons among the parameters (Tukey, 1977). Pearson correlation analysis was done to evaluate relations between all the parameters. The difference was considered statistically significant at $P \leqslant 0.05$. Statistical analyses were performed using IBM SPSS 20.0 statistical software (IBM Corp, 2011).

3 RESULTS

3.1 Relative abundance of intercepted beetles

Altogether 632 specimens comprised of six species of sap beetles were encountered in bait trap (Table 1). Out of six species, a single species (*Urophorus humeralis*) is represented by at least 56% of individuals (denoting the highest occurrence), while three species (*Carpophilus maculatus*, *C. jelineki* and *C. marginellus*) are represented by not more than 1% of individuals (denoting the lowest occurrence). Two other species (*Epuraea ocularis* and *E. luteola*) are represented by 21% and 20% of individuals (denoting moderate occurrence), respectively (Fig. 1).

Table 1 List of specimens of nitidulid species encountered in bait traps

Year	Month	Number of specimens collected						Total
		Urophorus humeralis	*Carpophilus marginellus*	*Carpophilus jelineki*	*Carpophilus maculatus*	*Epuraea luteola*	*Epuraea ocularis*	
2013 – 2014	4	10	–	–	–	–	8	18
	5	16	–	–	–	8	–	24
	6	11	–	–	–	4	4	19
	7	19	–	–	–	8	7	34
	8	14	–	–	–	–	9	23
	9	17	2	–	–	5	8	32
	10	21	–	–	–	11	5	37
	11	16	–	–	–	14	–	30
	12	19	–	–	–	–	–	19
	1	12	–	–	–	4	8	24
	2	14	–	3	2	11	12	42
	3	22	–	–	3	–	9	34
2014 – 2015	4	18	–	–	–	11	–	29
	5	18	–	–	–	–	–	18
	6	–	–	–	–	20	–	20
	7	15	–	–	–	–	8	23
	8	21	–	–	–	–	12	33
	9	13	–	–	–	4	4	21
	10	22	2	2	1	8	7	42
	11	12	–	–	–	5	6	23
	12	–	2	–	–	–	10	12
	1	12	–	–	–	5	4	20
	2	18	–	2	–	6	7	33
	3	14	–	–	–	–	8	22
Total		353	6	7	6	124	136	632
Proportion (%)		55.85	0.95	1.11	0.95	19.62	21.52	100

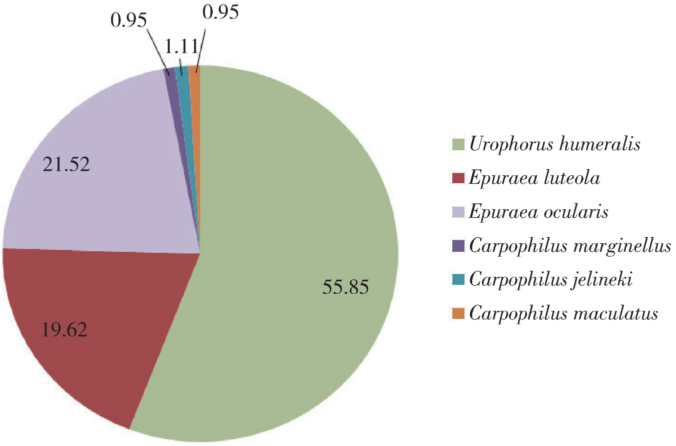

Fig. 1 Proportion of nitidulid species (%) during 2013 – 2015

3.2 Seasonal incidence

During the two-year time span, majority of species and specimens were captured during the months of September-October and February (Fig. 2). When the meteorological data (Table 2), *viz.*, temperature and relative humidity, were plotted along with the numbers of species and specimens in every month over the span of two years (Fig. 3), the graphical representations showed that the number of trapped specimens and species richness were the maximum in an optimum range of atmospheric temperature and relative humidity.

3.3 Correlation between species abundance and meteorological factors

Taking into consideration the months as 'pre-monsoon', 'monsoon' and 'post-monsoon' seasons, the abundance (%) of the sap beetles had not significantly varied between the two years ($F_{2,21} = 2.056$, $P > 0.05$) and within the different months of each year. A significant variation of temperature (℃) ($F_{2,21} = 51.725$, $P < 0.05$), relative humidity (%) ($F_{2,21} = 14.052$, $P < 0.05$), and total rainfall (mm) ($F_{2,21} = 16.085$, $P < 0.05$) was observed throughout the entire study period due to the seasonal variation of the environmental parameters. Similarly, no significant difference in abundance of sap beetles was observed between all months in the two consecutive years ($F_{11,12} = 2.665$, $P > 0.05$). However, significant variations of monthly temperature (℃) ($F_{11,12} = 92.656$, $P < 0.05$), relative humidity (%) ($F_{11,12} = 16.608$, $P < 0.05$), and total rainfall (mm) ($F_{11,12} = 3.720$, $P < 0.05$) were observed throughout the entire study period.

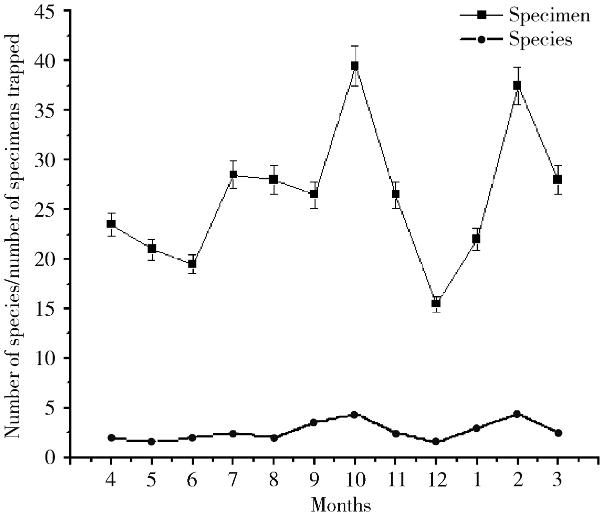

Fig. 2 Mean data of the number of specimens and species of sap beetles captured during 2013 – 2015

Table 2 Meteorological data and field data observed by using bait traps in 2013 – 2015

Year	Month	Maximum temperature (℃)	Minimum temperature (℃)	Mean temperature (℃)	Relative humidity (RH) at 08:30 am (%)	RH at 17:30 pm (%)	Mean RH (%)	Rainfall (mm)	Number of specimens of sap beetles			Number of species of sap beetles
									1st fortnight	2nd fortnight	Total	
2013 – 2014	4	36.6	25.4	31.00	70	54	62.0	31.2	11	7	18	2
	5	34.5	26.8	30.65	77	74	75.5	123.5	10	14	24	2
	6	33.5	27.0	30.25	80	79	79.5	397.5	10	9	19	3
	7	32.9	27.0	29.95	83	84	83.5	327.2	12	22	34	3
	8	32.1	26.3	29.20	87	85	86.0	679.2	13	10	23	2
	9	33.1	26.6	29.85	83	82	82.5	341.4	13	19	32	4
	10	31.1	24.5	27.80	86	85	85.5	523.1	19	18	37	3
	11	29.8	19.1	24.45	67	64	65.5	0.0	14	16	30	2
	12	27.0	15.8	21.40	75	63	69.0	0.0	8	11	19	1
	1	24.4	13.8	19.10	75	63	69.0	0.0	12	12	24	3
	2	28.2	16.9	22.55	71	53	62.0	41.5	18	24	42	5
	3	33.6	22.0	27.80	66	49	57.5	16.3	14	20	34	3
2014 – 2015	4	37.9	26.9	32.40	63	48	55.5	0.1	19	10	29	2
	5	36.9	27.4	32.15	71	63	67.0	101.4	8	10	18	1
	6	34.4	27.1	30.75	82	78	80.0	223.5	12	8	20	1
	7	33.0	26.9	29.95	83	81	82.0	375.8	7	16	23	2
	AUG	33.2	26.5	29.85	83	79	81.0	283.6	12	21	33	2
	SEP	33.5	26.3	29.90	82	78	80.0	322.1	12	9	21	3
	10	32.8	24.0	28.40	78	73	75.5	65.5	18	24	42	6
	11	30.8	18.9	24.85	64	63	63.5	0.0	14	9	23	3
	12	26.0	14.8	20.40	75	64	69.5	0.1	7	5	12	2
	1	25.6	11.4	18.50	78	63	70.5	3.2	10	10	20	3
	2	30.0	18.4	24.20	75	55	65.0	6.8	13	20	33	4
	3	33.4	22.2	27.80	63	46	54.5	53.5	12	10	22	2
Total								3 916.5	298	334	632	6

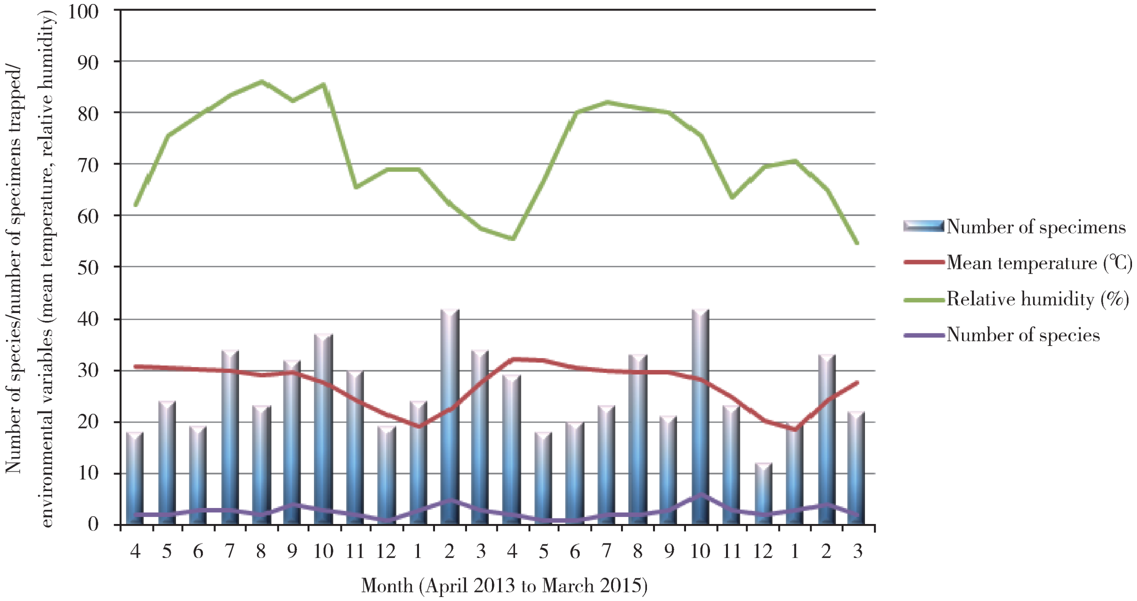

Fig. 3 Seasonal fluctuation of sap beetles with respect to environmental variables: mean temperature (℃) and mean relative humidity (%) in 2013 – 2015

Tukey (HSD) test was used to evaluate pair-wise multiple comparisons of seasonal variation of species abundance (%) and meteorological parameters. The results revealed no significant variations in species abundance (%) between the seasons ($P > 0.05$). However, temperature (℃) significantly varied between pre-monsoon and post-monsoon ($P < 0.05$) and between monsoon and post-monsoon ($P < 0.05$). The differences of relative humidity (%) and total rainfall (mm) between pre-monsoon and monsoon ($P < 0.05$) and between monsoon and post-monsoon period were found to be significant ($P < 0.05$) while between pre-monsoon and post-monsoon period, no significant differences were observed ($P > 0.05$). However, species abundance (%), temperature (℃), relative humidity (%) and total rainfall (mm) showed no significant variations ($P > 0.05$) in the consecutive two years. In consistent with previous trends, species abundance (%), temperature (℃), relative humidity (%) and total rainfall (mm) had not significantly varied ($P > 0.05$) while considering same seasons in two years. Pearson correlation analysis (r) revealed no significant correlation with species abundance (%) and environmental parameters (Table 3). However, a significant positive correlation was observed between temperature (℃) and rainfall (mm) ($r = 0.473$) and relative humidity (%) and rainfall (mm) ($r = 0.831$). The graphical representation showed that the number of trapped specimens and species richness were maximum in an optimum range of atmospheric temperature and relative humidity (Fig. 3).

Table 3 Correlation table (all parameters considering month and year; N = 24)

	Pearson analysis	Abundance	Temperature	Relative humidity	Total rainfall
Species abundance	Pearson correlation	1.000	0.074	0.050	0.070
	Sig. (2-tailed)		0.731	0.816	0.745
Temperature	Pearson correlation	0.074	1.000	0.258	0.473*
	Sig. (2-tailed)	0.731		0.223	0.020
Relative humidity	Pearson correlation	0.050	0.258	1.000	0.831**
	Sig. (2-tailed)	0.816	0.223		0.000
Total rainfall	Pearson correlation	0.070	0.473*	0.831**	1.000
	Sig. (2-tailed)	0.745	0.020	0.000	

* Correlation is significant at the 0.05 level (2-tailed); ** Correlation is significant at the 0.01 level (2-tailed).

4 DISCUSSION

A total of 632 sap beetle specimens belonging to six species were intercepted from the food bait trap. The most commonly collected sap beetle was *Urophorus humeralis*. This species was encountered for the largest number and during almost all months of the year. Other common species were *Epuraea ocularis*, and *E. luteola*. It was noticed that a suitable range of temperature (22℃ to 29℃) and relative humidity ranging from 62% to 86% (more conducive between 82.5% and 86%) in combination create a favourable situation for the population growth of the sap beetles. Different species entered into the trap in successive stages of the fermenting food. *Epuraea* spp. were intercepted in the first 12 h. *Carpophilus* spp. were intercepted in the next 12 h when the food started getting all the more soft due to fermentation. *Urophorus humeralis* was mostly found in later successive stage when the food in the bait trap was severely rotten.

The device and sampling protocol for population study was modest. However, the result of the study depicts a moderate richness of species, their changing incidences, and relative abundance among the available species in southern periphery of the city of Kolkata.

The population of sap beetles in a location over the span of few years and its fluctuations are the indicators of seasonal abundance of these beetles. While some sap beetles are known to inhabit flowers, the majority of its species were reported from dead and decaying fruits, fermenting sap and in fungi (Habeck, 2002). Magagula (2006) studied the habitat specificity and abundance of beetles in South Africa and found that nitidulid beetles were intercepted mostly from managed orchards and pine windbreaks. There has been a variation in the capture of the sap beetles in different seasons but it has not been possible to find out a direct correlation with any of the environmental factors and the abundance of sap beetles. While a little bit of rain boosted the occurrence in nature, continuous and high rainfall deterred abundance of the sap beetles. During the warm season (April to August), the beetles were intercepted moderately and with less fluctuation. But, they were captured more effectively during early (February) and late phases of the season (September to October). This observation was a point of interest, and possible reasons for this sort of behaviour of the sap beetles were tried to be found out. One of the possible reasons was that the available host materials in nature are not scarce, as there are a number of orchards or fruit growing plots in the sub-rural and rural areas around the study site or location of the bait trap. The fruits or natural host materials compete with the baits and that probably reduce overall captures in the bait traps. When the availability of the fruits in nature is in decline, the fruit baits in traps significantly enhance capture of the beetles. A comparable situation was noticed by Dowd and Nelsen (1994) in Central Illinois in United States in cornfield-oak wood habitat.

Different species of sap beetles were collected with varying baits like sugar and molasses (Frost and Dietrich, 1929), oak and maple block soaked with vinegar (Dorsey and Leach, 1956), banana pulp (Daughretty and Brett, 1966), *etc*. The chemical stimulus emanating from these substances vary and the responses of different saprophagous insects to these odour or chemical signals are variable. It appears that the chemical signals released from the fermenting banana bait change with time and attract different species. There is difference in how soon different sap beetle species become active with successive changes in chemical signals.

Species richness is simply the number of species in an area. Species diversity, however, really expresses the species richness. Diversity is the measure of relative abundance of the species or otherwise, the manner in which each species is represented by individuals. In the available data-set of six species, there are two extremes of diversity. In one extreme, a single species (*U. humeralis*) is represented by at least 56% of individuals (denoting the highest diversity), while three species (*Carpophilus maculatus*, *C. jelineki* and *C. marginellus*) are represented by not more than 1% of individuals (denoting the lowest diversity). Two other species (*Epuraea ocularis* and *E. luteola*) are represented by 21% and 20% of individuals (denoting moderate diversity), respectively. The area or extent of area is an important criterion in the study of species richness and diversity. The common consideration is that more species can be encountered in larger areas. This could not be testified. The sampling in a small area has been a major limitation in the evaluation of species richness and diversity, in the current study.

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印度加尔各答市区外围一地的露尾甲物种组成、多度和季节性发生

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摘要:【目的】印度大部分露尾甲在腐烂的水果和蔬菜上大量发生,其种群在一年中表现出明显的季节性波动。据推测,露尾甲种群很大程度上依赖于温度、湿度和降雨之类的环境因子。【方法】本研究调查了2013-2015年印度加尔各答市区外围一地Garia的露尾甲物种组成、季节性发生和种群结构,记录了其活跃时期、季节性多度和影响其发生的因素。【结果】调查期间在调查地共发现数目不等的6个物种。其中最常见露尾甲为*Urophorus humeralis*,它是个体数量最多的物种且在一年中几乎所有月份均有发生;其他常见物种为*Epuraea ocularis*和*E. luteola*。不同物种在食物发酵的连续阶段进入诱捕器中。最初12 h被捕获的是*Epuraea*属的种类,而在诱捕器中食物严重腐烂的后续阶段发现最多的是*U. humeralis*。在合适范围的气温(22~29℃)和相对湿度(82.5%~86%)下,物种丰富度最高,表明这些环境变量对露尾甲种群具有重要影响。【结论】加尔各答主要水果和蔬菜在季风后季节种植,在季风后季节取食这些作物的露尾甲发生量(物种丰富度和多度)最高。这一研究结果可能有助于制定针对这些甲虫的有效田间治理策略。

关键词: 露尾甲科; 露尾甲; 物种多样性; 季节性变化; 环境因子; 加尔各答; 印度

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